A DECADE OF GROWTH OF DISTANCE LEARNING UNIVERSITIES (DLUs). TOWARDS AN URGENT DIGITAL AND STEM APPROACH

UN DECENNIO DI CRESCITA DELLE DISTANCE LEARNING UNIVERSITIES (DLUs). VERSO UN URGENTE APPROCCIO DIGITALE E STEM

Gaia Turconi
Università Telematica Pegaso
gaia.turconi@unipegaso.it

Lucia Martiniello
Università Telematica Pegaso
lucia.martiniello@unipegaso.it

Double Blind Peer Review

Citazione
Turconi, G., & Martiniello, L. (2024). A decade of growth of Distance Learning Universities (DLUs). Towards an urgent digital and STEM approach. *Italian Journal of Health Education, Sports and Inclusive Didactics*, 8(2), Edizioni Universitarie Romane.

Doi:
https://doi.org/10.32043/gsd.v8i2.1091

gsdjournal.it
ISSN: 2532-3296
ISBN 978-88-7730-493-3

ABSTRACT
Distance Learning Universities (DLUs) are growing in educational offerings and student participation and can play an essential role in the digitization of learning. The analysis presented here focuses on their impact in the Italian context, and particularly in the STEM area, where innovations in teaching methods and resource management are required. ANVUR report, European Community and Ministry of Education and Merit show how the issue is pedagogical, social and economic.

Le Università a Distanza (DLUs) stanno crescendo in offerta formativa e partecipazione studentesca, e possono svolgere un ruolo essenziale nella digitalizzazione dell'apprendimento. L'analisi qui presentata si concentra sul loro impatto nel contesto italiano, e in particolare nell'area STEM, dove si richiedono innovazioni nel metodo didattico e nella gestione delle risorse. Rapporto ANVUR, Comunità Europea e Ministero dell'Istruzione e del Merito mostrano come la questione sia pedagogica, sociale ed economica.

KEYWORDS
Distance Learning Universities, STEM, digital education, mathematics
Università Telematiche, STEM, educazione digitale, matematica

Received 29/04/2024
Accepted 12/06/2024
Published 24/06/2024

1. Introduction: tertiary education and digital learning

Education - and tertiary education in particular - has been greatly influenced by the growing presence of digital, leading distance learning universities to play an increasingly central role. In this context, the use of technologies in STEM disciplines (Science, Technology, Engineering, Mathematics) emerges as a topic of considerable interest, as in some cases it seems to make a not insignificant contribution to solving the unique challenges that the teaching of this discipline presents. This paper aims to contribute to the reflection in the field of STEM learning-teaching, highlighting how the peculiarities of digitization can frame Distance Learning Universities (DLUs) as a privileged educational environment to address the teaching challenges of science education.

Italian students in traditional and digital universities: an increasing trend toward online

In the academic year 2021/2022, there were 1,949,481 students regularly enrolled in university courses (ANVUR, 2023), distributed in the 99 universities in the territory, of which 11 are distance learning. The latter appear to be located mainly in the center of the peninsula (*ibidem*), although this figure refers only to administrative locations: by their very nature, Distance Learning Universities are spread widely throughout the territory to support the teaching, evaluation, and orientation services of enrolled students.

The recent Report of the National Agency for the Evaluation of the University System and Research (ANVUR) regarding higher education in Italy shows how the number of university students has drastically increased in the last decade, mainly thanks to the DLUs that have quintupled the number of their enrolled students reaching about 224 thousand: as of today, therefore, one in ten students choose a telematic university (see Fig. 1). For example, if we look at the data available on Higher Education Data Portal, a platform of the Ministry of Universities and Research, we can see that the Pegaso Telematic University counts more than 90 thousand enrolled in the a.y. 2022/2023, surpassing even the Alma Mater Studiorum of Bologna, which held the record as the most attended university in Italy until 2018 (USTAT, 2023), and fast approaching the numbers of the University of Rome La Sapienza, which is attended by almost 110 thousand students.

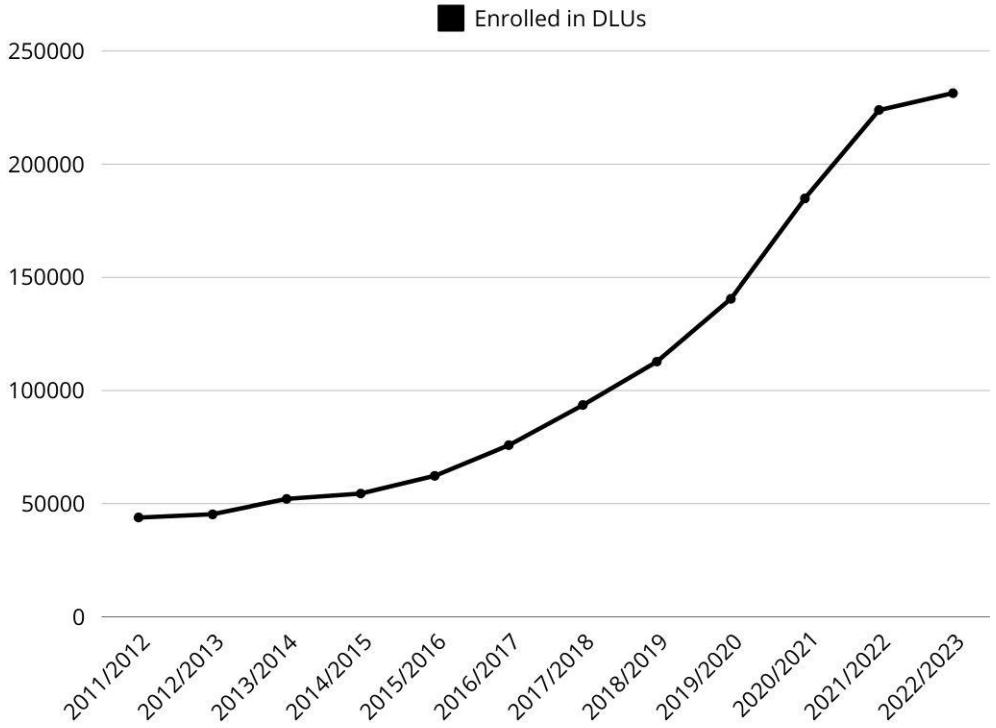


Figure 1. Enrolled in DLUs for a decade (USTAT, 2023).

Looking specifically at the data on freshmen students, whose growth trend is comparable to that of the total number of enrolled students, it can be observed that in the face of a general increase, distance learning universities acquired 7.5% of total first-year students - they were 1.6% in the 2011/2012 academic year - corresponding to 24,951 students out of 331,502 total (ANVUR, 2023). The geographic distribution of these students is quite equivalent to that relating to students at traditional universities, showing how interest in digital and distance learning is not related to the region of residence but equally affects all areas of the peninsula (Table 1).

Type of University	**a.y.**	**Geographic area of residence**					
		North-West	**North-Est**	**Center**	**South**	**Islands**	**Abroad**
Traditional	2011/ 2012	23,0%	16,7%	20,3%	28,1%	10,7%	1,2%

	2021/ 2022	23,6%	17,7%	25,0%	25,0%	10,6%	2,4%
DLU	2011/ 2012	16,2%	9,7%	27,8%	27,8%	13,7%	1,5%
	2021/ 2022	23,5%	13,1%	28,3%	28,3%	14,5%	1,6%
Total	2011/ 2012	22,8%	16,6%	28,1%	28,1%	10,8%	1,2%
	2021/ 2022	23,6%	17,7%	25,3%	25,3%	10,9%	2,4%

Table 1. Geographic area of residence of first-year students (ANVUR, 2023).

The trend of enrolling in DLUs to pursue a second degree is an increasing phenomenon, reflecting the growing interest in further education and retraining initiatives very often linked to new labor market needs. Students enrolled in DLUs with prior experience at traditional universities make up an increasing share of total enrollment, rising from 40% to 45% in ten years, translating into a numerical increase from 18,000 to about 100,000. However, the predominant demographic group remains that of students embarking on their first college experience. The populousness of this category has grown from 26,000 to 122,000, marking the persistent appeal of DLUs as a pathway to college education (see Fig. 2).

It is interesting to analyze the latter information in light of the age of the enrolled students, which is particularly evident in the increase of students in their 20s and 30s: the cohort of young people under the age of 23 has seen a substantial surge, rising from 8.4% to 20.6% (see Fig. 2).

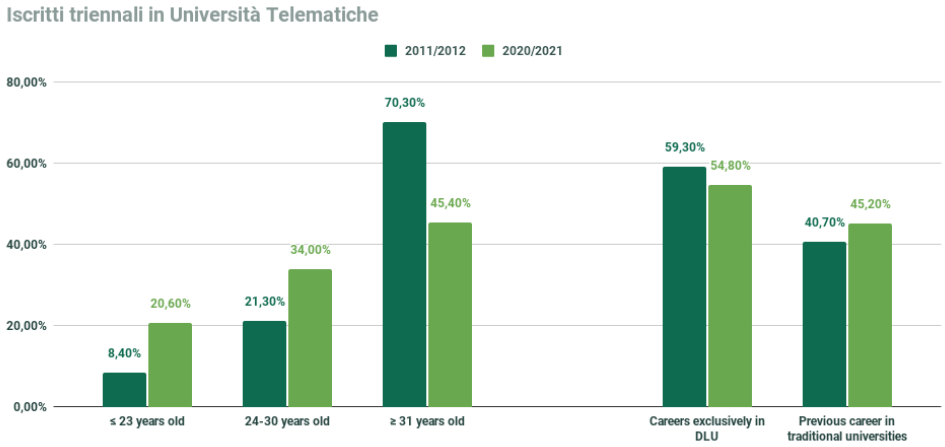
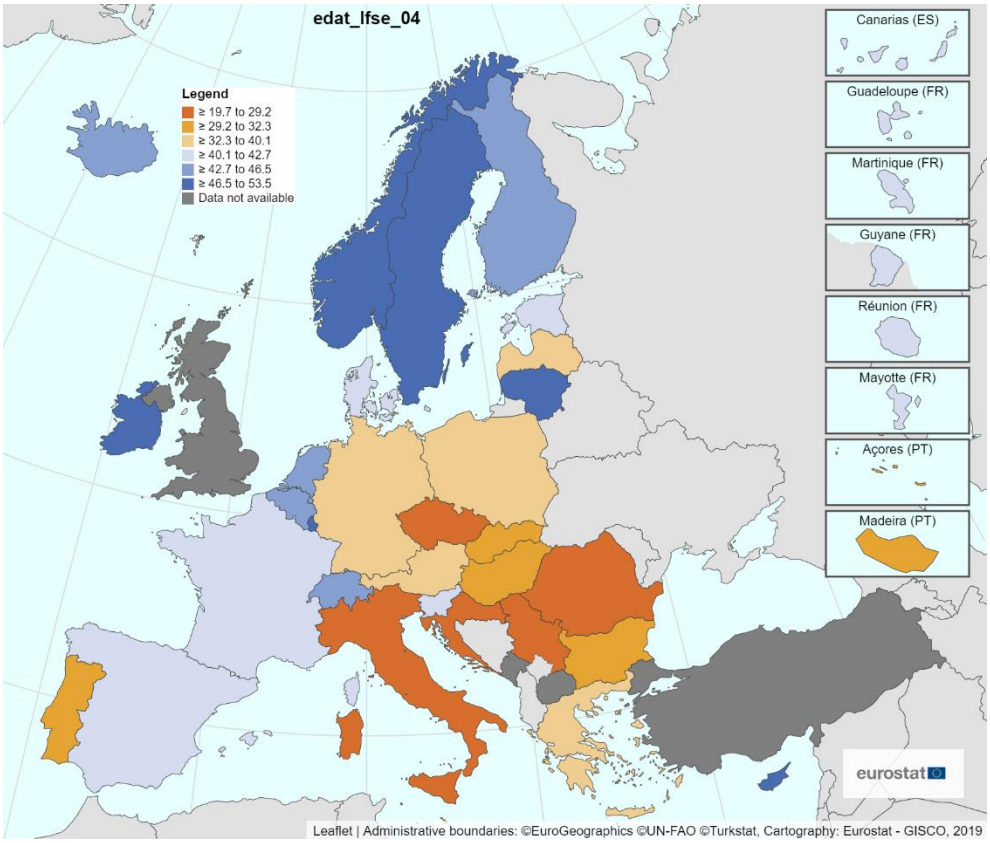


Figure 2. Characteristics of students in DLUs ten years later (USTAT, 2023).

Given the increase in the number of students enrolled in tertiary institutions, the resulting increase in bachelor's degrees awarded in a.y. 2021/2022 is not surprising: of the approximately 345,000 graduates (up from 298,000 in 2011/2011), 10% come from DLUs (up from 2% in 2011/2012). Interestingly, the percentage of students earning a bachelor's degree within the normal course length is higher at DLUs (44.8 percent) than at traditional universities (37.8 percent). Among traditional universities, the differences "depend to a great extent on differences at the level of geographic area" (ANVUR, 2023, p. 56): in fact, it occurs that in the Center (30%-35%) and in the South and Islands (25%-30%), these values drop a lot compared to the North (40%-45%).

Although the data of graduates in the Italian territory is on the rise compared to the previous decade, when compared to the European average it highlights how there is still a need for improvement: Italy ranks very low in the rankings, with just over 20% of doctors with (at least) a three-year degree compared to a European percentage of almost 35% (see Fig.3), as reported by EUROSTAT data (EUROSTAT, 2023).



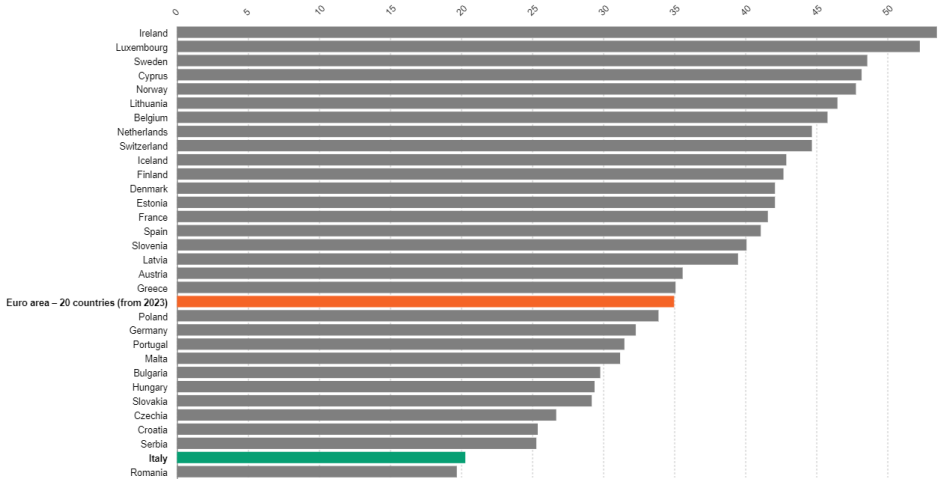


Figure 3**.** Data visualizations of population percentage by tertiary educational attainment level (EUROSTAT, 2023).

Of those who enroll at the University, then, one in five students (20%) drop out before obtaining their degree, a value that increases to one in 4 students (25%) six years after matriculation. This figure, which is decreasing compared to the previous decade but across all universities, mainly affects students who graduated in the technical-professional area and reside in Central Italy or the Islands. The phenomenon of dropouts is not limited, therefore, only to the transition between the first and second university years, highlighting the need for more effective entry orientation actions but also for more mentoring and support policies for the entire study cycle (ANVUR, 2023).

Italian undergraduate courses and some problems in STEM area

Over the decade 2011/2021, the ANVUR Report on the State of the Italian University and Research System highlights impressive growth in the educational offerings of digital universities in particular, as evidenced by the increase from 70 degree programs in 2011/2012 to 149 in 2021/2022 (see Fig. 4), compared with a 10% increase in the educational offerings of traditional universities.

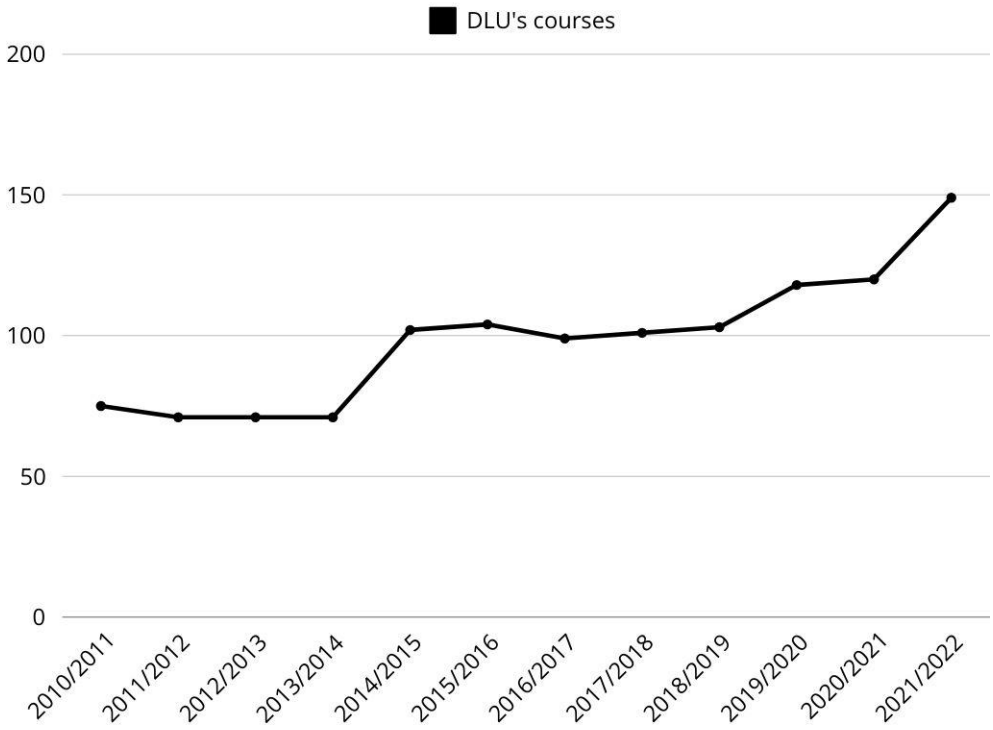


Figure 4. Undergraduate courses available at DLUs (USTAT, 2023).

Analyzing the educational offerings from a disciplinary point of view, then, the STEM area in Italy appears to be broader than other academic areas, but despite this, students seem to prefer the Economics and Law area, which has the largest number of enrollments nationwide; the choice of Distance Learning Universities, then, seems to really follow the line dictated by students' preferences (see Table 2).

a.y. 2021/2022	STEM	Health and Agri-veterinary	Economics and Laws	Arts, Literature and Education
Undergraduate courses offer	35%	25.6%	23.9%	15.5%
Enrolled in undergraduate courses	26.8%	18.4%	34.4%	20.4%
Undergraduate courses offered in DLUs	25.5%	6.7%	45.6%	22.1%

Table 2**.** Undergraduate courses offer and their enrollees in Italy by subject area in a.y. 2021/2022.

The literature suggests how the problems encountered in STEM education affect an already fragile situation such as the transition from secondary to tertiary education; we also note this by looking at data on the Delayed Graduation Index, calculated through the ratio of years of delay to normal course length, which, although it has decreased for all disciplines, remains above 0.4 for the STEM area (AlmaLaurea, 2023) (see Fig.5).

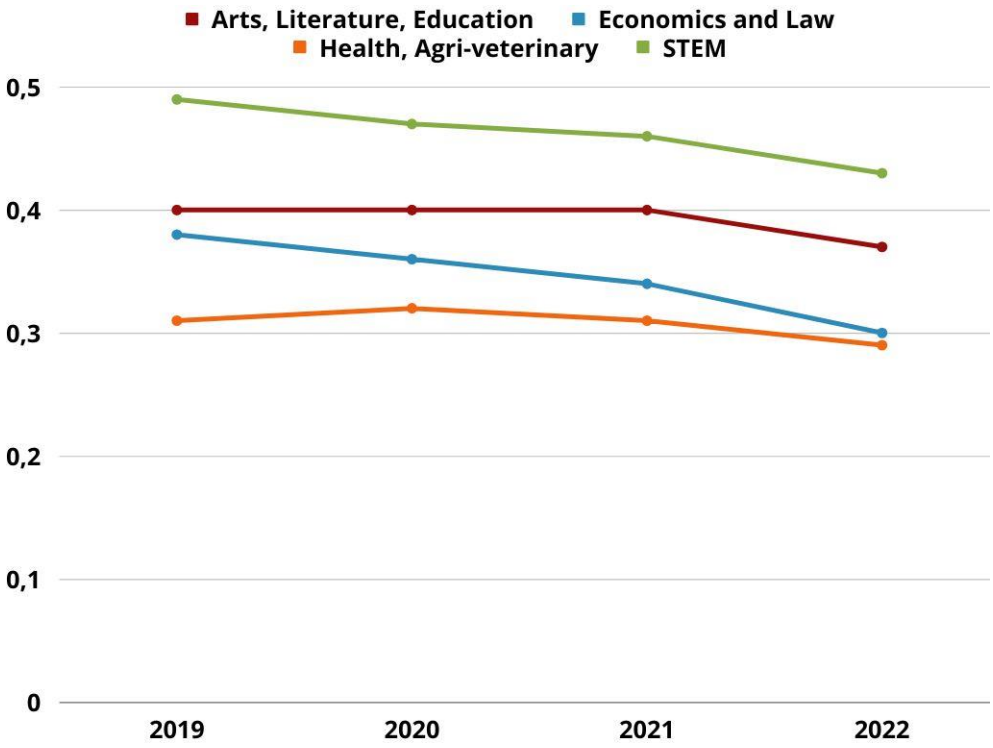


Figure 5**.** Late graduation index for bachelor's degree by subject area (AlmaLaurea).

Looking at the Distance Learning Universities, we notice how the number of courses delivered and students enrolled has also grown by the trend highlighted in the previous paragraph (see Fig. 6). Currently, there are eleven DLUIs in Italy (UniMarconi, UniTelma Sapienza, Leonardo da Vinci, UniNettuno, UIL, E-Campus, Giustino Fortunato, Pegaso, San Raffaele, Mercatorum, UniCusano), and only seven of them offer courses in the STEM area: all seven offer at least one course in engineering, three offer courses related to the science area (such as biology), and only one offers a course in statistics, thus relevant to the mathematics area.

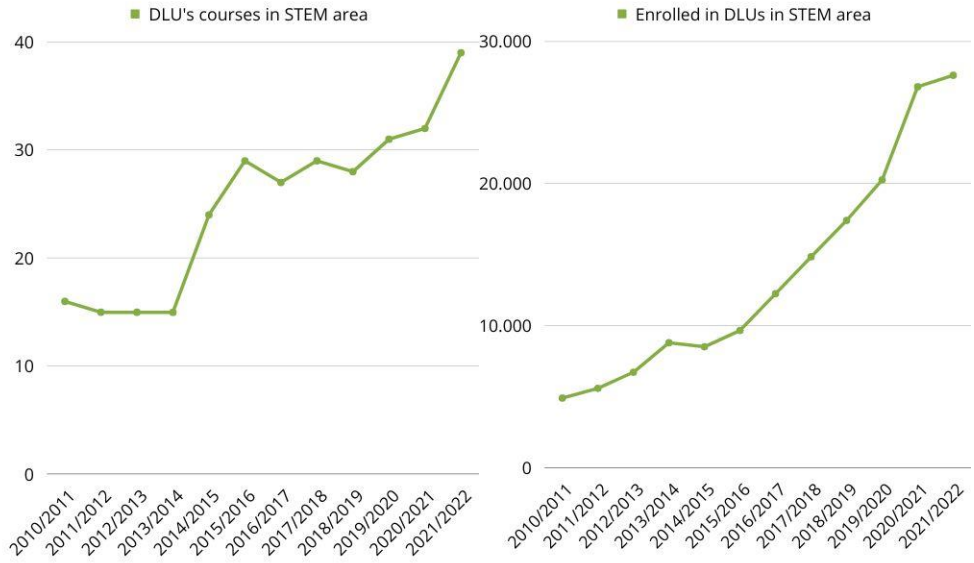


Figure 6. Courses and enrolled in STEM area in DLU over a decade (USTAT, 2023).

It is important to note that a degree in STEM disciplines is in high demand in the international and Italian labor market; statistical logistic regression analyses conducted by the AlmaLaurea University Consortium and presented in the 2023 report (*ibidem*) show that graduates from the STEM group are among the favored - all other things being equal - in terms of employment chances 1-3-5 years after graduation. The same is true for average salaries, where STEM graduates can earn more than 100 euros per month more than graduates from the political-social and communication group (*ibi*).

A decade of growth for DLUs

The growth of the DLU system since its establishment in 2004 can be attributed to a complex interaction of social, economic, and technological factors. These factors require continuous monitoring, facilitated by recurring data surveys and specialized academic studies, with particular focuses of attention on specific educational, disciplinary, and structural aspects. Of particular impact has been the opportunity provided by these universities for quality distance learning, which has facilitated access to tertiary education for many students, an aspect that is still very critical in

Italy. Distance Learning Universities offer a pathway for working professionals, people residing in geographically marginalized areas, and those with special educational needs who are often hindered from pursuing a college career. The pandemic-induced shift to distance education highlighted the robustness of DLUs and their ability to adapt to difficult circumstances. This unforeseen event further highlighted the importance of digital education, solidifying the position of Distance Learning Universities as leaders in innovative and resilient educational methodologies.

DLUs, experts in both synchronous and asynchronous distance learning methods, have ably responded to the needs of the health emergency (Martiniello et al., 2022). Students enrolled in these universities, in fact, did not experience any difficulties during the abrupt "transition to online" and did not have to rapidly fill any gaps in their digital skills, as happened to students at presential universities. This trend was maintained even after the cessation of the blocking measures, underscoring the effectiveness of digital learning methodologies in the overall university system.

Distance universities, therefore, face several challenges both in terms of enhancing a positive trend and in terms of the quality of their educational offerings. The data analyzed so far highlight how the nontraditional, multimedia approach typical of these universities is making more and more room within the Italian tertiary educational landscape, finding favor with students.

Could DLUs, then, play a central role in addressing the tough issue of STEM education in Italy? Could they contribute to the development of a greater culture and more skills that are useful and transversal to the country system to face the great challenge of digitization and new labor and social inclusion policies?

2. Learning with Digital Technologies in STEM

"Guidelines for STEM" in the Italian Education System.

The Ministry of Education and Merit (MIM) on October 23rd, 2023, issued the "Guidelines for STEM Disciplines" warning of the need to introduce "dedicated actions to strengthen in curricula the development of mathematical-scientific-technological and digital skills related to the specific fields of experience and the learning of STEM disciplines, including through innovative teaching methodologies" (MIM, 2023). These are part of the National Recovery and Resilience Plan (PNRR), which envisions reforms in the administrative, legal, economic, and educational spheres to accelerate the ecological and digital transition (Prime Minister, 2021), in

which it is made explicit how intervention in STEM disciplines can only take place in the face of a new cross-cutting educational paradigm of a methodological nature. Assuming strategic relevance are the 4Cs of STEM disciplines or the four key competencies enhanced by an interdisciplinary mathematical-scientific-technological approach: Critical Thinking, Communication, Collaboration, and Creativity. It is important to emphasize the central role of the latter competence, creativity, which is often neglected but highlighted by the European Union through the introduction of the term *STEAM*, where the addition of the A identifies the so-called *Arts and Humanities* (European Education Area), and which inevitably requires a methodological approach of interdisciplinary views. All this constitutes and contributes to the development of the teaching of STEM and STEAM disciplines, which can certainly find full realization in teaching practice through the use of a variety of training methodologies that are not only traditional but highly innovative, for example, a laboratory approach, methodologies such as learning-by-doing, problem-solving, cooperative learning, critical thinking, and problem-based learning.

Particular emphasis is then placed on life experiences - particularly in university and adult education - and their teaching potential, which can foster engagement through building on prior knowledge and skills acquired in formal, nonformal, and informal contexts.

The new educational paradigm must necessarily also involve the aspect of assessment, which must be based primarily on reality tasks and systematic observations, shifting the focus from summative to formative assessment. By exploring the facets of learning in STEM fields, it is possible to focus on mathematics as a paradigmatic example that allows us to examine different teaching methodologies. Indeed, this emerges as a key discipline in the science area: its language provides the basis for deep analysis and understanding of scientific phenomena, concepts, and models. Consequently, it serves as a common thread since, as Galileo Galilei wrote, *the book of nature is written in mathematical language*.

Secondary to tertiary transition: a crisis to handle.

Entry into the university world, especially in STEM fields and that of mathematics in particular, represents a significant educational and research challenge (Gueudet, 2008). This stage is a real *crisis* from an anthropological perspective: Clark and Lovric (2008), describe the transition from secondary to tertiary education as a *rite of passage* for students, characterized by both cognitive conflict and culture shock.

By the former term, they refer to situations in which new knowledge is incompatible with already acquired knowledge because the internalized model of interpreting the material (the so-called *explanatory framework*) is not suitable for understanding the new material that is being presented and studied for the first time. This happens when, for example, students continue to use study and learning methods that were functional in high school but are no longer functional in the tertiary context, given the complexity of the new topics and the level of depth with which they are treated (De Guzmán et al., 1998). The second term, culture shock, on the other hand, is related to the emotional world of the individual facing this transition, which at this stage of disturbance is so pointed that it influences the individual's behavior.

The encounter with tertiary education, therefore, is not only about the transition from one cultural institution to another (Artigue, 2004) and from a praxeological approach that privileges "knowing how to do" - typical of high schools - to one that privileges "knowing" (D'Amore & Godino, 2008, p. 10), but also requires a profound change in relational models with peers and educational figures of reference. A common observation among teachers-academic and non-academic-is, in fact, that students replicate the practices proposed by teachers without fully understanding them or grasping their underlying meanings (Gueudet & Pepin, 2018); this tendency, closely related to the explanatory framework mentioned earlier, is not only one of the most common causes of failure in the university context but also increases the risk of reducing mathematical learning to a mere memorization of procedures, interfering with authentic mathematical understanding (Pepin, 2014) and undermining the fundamental process of acquiring a relational view of the discipline (Skemp, 1976), focused on understanding meanings and patterns useful for developing the skills necessary and essential to the adaptive and resilient necessity of social and economic change.

Apprendimento digitale e tecnologie

Over the years, technology has become an increasingly pervasive part of the educational environment: one of the first steps technology took in schools was in the STEM disciplines, where the introduction of handheld calculators marked a crucial node in the integration of technology in education. Since then, various technological innovations have found their way into classrooms, even if with a predominant focus on enhancing computational skills and simplifying tasks, providing students with the ability to tackle different tasks with greater autonomy and without teacher support (Ruthven, 2012), thus also fostering a change in pedagogical practices.

However, it is crucial to consider technology as a tool for "transforming thinking" (Hegedus and Moreno-Armella, 2009, p. 398), and not as a mere computational tool (Bhat, 2023) or "as a kind of prosthesis to support old styles of pedagogy or curricular standards" (Hegedus and Moreno-Armella, 2009, p. 398); by taking a holistic approach to technology integration, educators can take full advantage of its potential to facilitate cognitive understanding and foster a positive emotional-relational approach to different science disciplines.

Over the past two decades, thanks in part to the skyrocketing development of the potential of technologies and digital technology, the need to reevaluate and rethink new and different foundational aspects of teaching has arisen overwhelmingly. The Teaching Triangle, which centers Teacher, Student, and Disciplinary Knowledge (Chevallard, 1986), innovates into an Instructional Tetrahedron that also includes Resources (Ruthven, 2012), which become a foundational part of instructional design and research. In the digital learning landscape, the concept of "resources" is very broad and includes "physical" digital elements, such as e-books and shared workbooks, and "social" elements, such as discussion forums, Padlet, and Classroom (Gueudet & Pepin, 2018). This influence of technology to support instructional methodologies has then fostered the already desirable and desired transition from a teacher-centered approach to more collaborative and cooperative learning experiences; virtual classrooms, online resources, and collaborative platforms have become commonplace, providing students with opportunities for self-directed learning and collaboration with peers beyond the confines of the physical classroom. These tools have the potential to foster greater personalization of school and academic pathways, considering the difficulties each learner may face without neglecting the social and collaborative aspects of learning (Bardelle & Di Martino, 2012). This personalized approach enhances students' engagement and understanding, fostering a more inclusive and effective educational environment, which is especially crucial in the transition phase from secondary to tertiary education to support students' journey toward autonomy and self-regulation (Zimmerman, 2000).

The integration of technology in education has also crashed geographic barriers, fostering the democratization of culture: students can now access educational content and interact with experts from around the world, broadening their perspectives and promoting a globalized approach to learning, also thanks to the availability of online courses open to all (MOOCs).

Scientific research in education highlights not only the potential of the tools but also their actual positive impact on learning, especially in STEM disciplines such as

physics, mathematics, biology, and chemistry (Roffi, 2023; Iannella et al., 2021). Dynamic geometry software such as GeoGebra and intelligent tutor systems have achieved significant results (Hillmayr et al., 2020): adaptive digital tools allow students to receive content tailored to their learning styles, providing immediate individualized feedback and preventing the formation of misconceptions, which are especially common in the early stages of math and science learning (D'Amore & Sbaragli, 2005). The use of digital tools in teaching and learning can foster student motivation and performance. What has been quickly stated is also reflected in self-determination theory (Nicholls et al., 1990): "the opportunity to make autonomous decisions during the learning process (i.e., autonomy) and to deal with challenging but not overly complex tasks (i.e., competence) can be realized through the integration of instructional features-such as feedback, pacing, and guided guidance-in digital media" (Hillmayr et al., 2020, p. 4). In these contexts, then, the system becomes a tutor as defined by Balacheff and Sutherland (1999), as an educational agent that intervenes in the learning process of students. This, however, is not enough and invites reflection: alongside the ease of use of digital resources, the risk arises that students unknowingly find themselves trapped in a "false sense of security, resulting in procrastination" (Wold, 2018, p. 2). There arises, therefore, an urgent need for a digital mediator, a guiding figure who can assist students in developing the autonomy needed to make effective use of the resources available to them. The digital mediator assumes a crucial role not only in helping students navigate the vast digital landscape but also in addressing the emotional aspects of learning. These aspects, which are in danger of being overlooked in a fully digital and distance learning context, are critical to ensuring a complete learning experience (Albano, 2022). The presence of professional guidance ensures that students not only use digital resources effectively but also help promote a balanced approach to using these tools. This is essential to prevent the "convenience" of digital resources from resulting in procrastination that is detrimental to learning.

The focus on the study of STEM subjects does not only respond to the needs of the new labor market and new social development policies, but rather enables and reinforces the need to train students for an ever-changing society and to develop skills that strengthen resilience and adaptation to social change empowered by the strong digital and technological push.

Navigating this intricate environment requires a holistic approach, where routinized learning and procedural understanding are only part of the process of learning and subject development. It requires a visionary effort of pedagogy and

teaching that incorporates conceptual understanding, analytical reasoning, and the ability to apply mathematical principles in different contexts. By addressing these challenges, educators can intrigue and attract students to STEM disciplines and more particularly to mathematics so that they not only succeed academically but also become actors in the change and governance of technology and digital in today's globalized society with an open eye to social cohesion.

3. Final reflections

We are in a phase of full digital transition that will inevitably lead to more education in the STEM fields, but the educational peculiarities of these disciplines seem to alienate students, as we have attempted to portray in our reflection and as evidenced by the discouraging results of Italian students in the INVALSI (2023) and PISA (2018) tests, where the basic skills, and in particular those in the science area, seem to be misaligned with the digital transformation and the new skills needed to accompany and govern change.

In this historical moment of great technological expansion, distance learning universities cannot shy away from meeting this educational challenge, especially since “digitization is breaking the physical environmental barriers found in democratized learning and classical classrooms, and the temporal ones such as defining a certain age to learn, learning in defined schedules” (Ali et al., 2023, p. 20), making learning more accessible for any type of student, young or adult and even for those embarking on complex careers such as STEM disciplines.

In this context, there emerges the need to reevaluate the role of methodological-didactic support, facilitator, mentoring and tutoring processes that have long been recognized as fundamental in the relevant literature. In particular, in asynchronous and blended environments, it is critical not only to facilitate the complex transition to Advanced Mathematical Thinking, as outlined by Tall (1991), but also to effectively support students in the appropriate management of instrumental and digital resources (Wold, 2018) and in the development of autonomy and self-regulation (Zimmerman, 2000) necessary to successfully address advanced-level curricula (Di Martino & Maracci, 2009). New needs in the STEM educational environment and digital learning are emerging more strongly and demanding timely responses, requiring further and necessary research to be actors in the social challenges to which we are now called to prepare a future citizenry capable of inhabiting and living a democratic, inclusive, and sustainable future.

For evaluation purposes, Lucia Martiniello is to be credited with writing section 1, Gaia Turconi with writing section 2, both with writing section 3.

References

Albano, G. (2022). Orchestrating affective, cognitive and metacognitive dimensions of undergraduate mathematics learning in digital environments. In: Hodgen J. et al. (eds.), Proceedings of the Twelfth Congress of European Research in Mathematics Education (CERME12), ERME / Free University of Bozen-Bolzano, Bolzano, pp. 2323-2330, https://hal.science/hal-03750558

Ali, L., Sorrentino, C., Martiniello, L. (2023). Personalized learning in the era of digital learning and artificial intelligence: futuristic perspectives and challenges. Giornale italiano di educazione alla salute, sport e didattica inclusiva, 7 (1), https://doi.org/10.32043/gsd.v7i1.856

AlmaLaurea (2023). Sintesi della XXV Indagine AlmaLaurea sulla Condizione occupazionale dei Laureati. Rapporto 2023. https://www.almalaurea.it/sites/default/files/2023-07/rapportoalmalaurea2023-sintesi-occupazione.pdf

ANVUR, (2023). Rapporto sullo stato del sistema universitario e della ricerca 2023.

Artigue, M. (2004). Le défi de la transition secondaire-supérieur. Que peuvent nous apporter les recherches en didactique des mathématiques?. Paper presented at the first French-Canadian Congress of Mathematical Sciences, Toulouse. https://doi.org/10.3406/dsedu.2002.1010

Bardelle, C., & Di Martino, P. (2012). E-learning in secondary–tertiary transition in mathematics: For what purpose? *ZDM*, 44(6), 787–800. https://doi.org/10.1007/s11858-012-0417-y.

Balacheff, N., & Sutherland, R. (1999). Didactical complexity of computational environments for the learning of mathematics. International Journal of Computers for Mathematical Learning, 4, 1–26.

Bhat, R.A. (2023). The Impact of Technology Integration on Student Learning Outcomes: A Comparative Study. International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET), 2(9), 592–596. https://doi.org/10.54443/ijset.v2i9.218

Chevallard, Y. (1986). La transposition didactique. Du savoir savant au savoir enseigné. Revue française de pédagogie, 76, pp. 89-91. Grenoble.

Clark, M. & Lovric, M. (2008). Suggestion for a theoretical model for secondary-tertiary transition in mathematics. Mathematics education research journal, 20(2), 25-37.

D'Amore, B., Godino, J.D. (2008). Punti di vista antropologico ed ontosemiotico. Didattica della Matematica. La matematica e la sua didattica, 1, pp. 9-38.

D'Amore, B., Sbaragli, S. (2005). Analisi semantica e didattica dell'idea di "misconcezione". La matematica e la sua didattica, 2, pp. 139-163.

De Guzmán, M., Hodgson, B. R., Robert, A., & Villani, V. (1998). Difficulties in the passage from secondary to tertiary education. In Proceedings of the International Congress of Mathematicians, 3, pp. 747-762. Berlin: Documenta Mathematica.

Di Martino, P., Maracci, M. (2009). The secondary-tertiary transition: beyond the purely cognitive. In: Tzekaki, M., Kaldrimidou, M., Sakonidis, C. (eds.). Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education, vol. 1, pp. 401-408. Thessaloniki, Greece: PME.

European Education Area. Relevant and high-quality higher education, https://education.ec.europa.eu/it/education-levels/higher-education/relevant-and-high-quality-higher-education, (ultima consultazione, marzo 2024).

EUROSTAT, (2023). https://ec.europa.eu/eurostat/en/ (ultima consultazione, marzo 2024).

Gueudet, G., Pepin, B. (2018). Didactic Contract at the Beginning of University: a Focus on Resources and their Use. Int. J. Res. Undergrad. Math. Ed. 4, pp. 56–73, https://doi.org/10.1007/s40753-018-0069-6

Gueudet, G. (2008). Investigating the secondary–tertiary transition. Educational studies in mathematics, 67(3), pp. 237-254, https://doi.org/10.1007/s10649-007-9100-6

Hegedus, S., & Moreno-Armella, L. (2009). Introduction: the transformative nature of ''dynamic'' educational technology. *ZDM—The International Journal on Mathematics Education*, 41(4), 397–398.

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., Reiss, K.M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. Computers & Education, 153, 103897, https://doi.org/10.1016/j.compedu.2020.103897

Iannella, A., Morando, P., Spreafico, M.L. (2022). Challenges in Mathematics Learning at the University: An Activity to Motivate Students and Promote Self-awareness. In: Casalino, G., et al. (eds.), Higher Education Learning Methodologies and Technologies Online. HELMeTO 2021, pp. 321-332. Cham: Springer International Publishing, https://doi.org/10.1007/978-3-030-96060-5_23

INVALSI (2023). Rapporto invalsi 2023.

Martiniello, L., Sorrentino, C., Iannaccone, S., Vivona, A. (2022). Strategie di inclusione e partecipazione nella formazione universitaria. Indagine sui risultati di apprendimento raggiunti dagli studenti in Scienze motorie in periodo pandemico. Formazione & Insegnamento, 20(1). Pensa Multimedia Editore, https://doi.org/10.7346/-feis-XX-01-22_08

Ministero dell'Istruzione e del Merito (2023). Linee guida per le discipline STEM, https://www.miur.gov.it/web/guest/-/nota-prot-4588-del-24-ottobre-2023, (ultima consultazione, marzo 2024).

Nicholls, J., Cobb, P., Wood, T., Yackel, E., & Patashnick, M. (1990). Assessing student's theories of success in mathematics: individual and classroom difference. *Journal of Research in Mathematics Education*, *21* (2). https://doi.org/10.5951/jresematheduc.21.2.0109

Pepin, B. (2014). Using the Construct of the Didactic Contract to Understand Student Transition into University Mathematics Education. Policy Futures in Education, 12(5), pp. 646–657, https://doi.org/10.2304/pfie.2014.12.5.646

Programme for International Student Assessment PISA (2018). Results from Pisa 2018.

Presidente del Consiglio (2021). Piano Nazionale di Ripresa e Resilienza, https://www.governo.it/sites/governo.it/files/PNRR.pdf, (ultima consultazione, marzo 2024).

Roffi, A. (2023). STEM e tecnologie digitali: una indagine sulle pratiche didattiche dei docenti della scuola secondaria di II grado. In: New literacies. Nuovi linguaggi, nuove competenze. Book of Abstracts, pp. 69-71. Editrice Morcelliana.

Ruthven, K. (2012). The didactical tetrahedron as a heuristic for analysing the incorporation of digital technologies into classroom practice in support of investigative approaches to teaching mathematics. ZDM Mathematics Education 44, pp. 627–640. Springer, https://doi.org/10.1007/s11858-011-0376-8

Skemp, R. (1976). Relational Understanding and Instrumental Understanding. Mathematics Teaching, 77, pp. 20–26.

Tall D. (ed.) (1991). Advanced mathematical thinking. Mathematics Education Library, Springer, Dordrecht, vol. 11.

USTAT, (2023). Portale dei Dati dell'Istruzione Superiore, Ministero dell'Università e della Ricerca, https://ustat.mur.gov.it (ultima consultazione, marzo 2024).

Wold, M. (2018): Students' usage patterns of video recorded lectures in an undergraduate mathematics course. In: INDRUM 2018, INDRUM Network, University of Agder, Kristiansand, Norway, https://hal.science/hal-01849929

Zimmerman, B.J. (2000). Attaining self-regulation: A social cognitive perspective. In: Boekaerts, M., Pintrich, P.R., Zeidner, M. (eds.), Handbook of self-regulation. Academic press, pp. 13-39, https://doi.org/10.1016/B978-012109890-2/50031-7